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CHEMISTRY

The world war has emphasized as never before the essential part which chemistry plays not only in modern warfare, but in industry, agriculture, and commerce as well. While chemical knowledge and inventive genius has been concerned with the manufacture of high explosives, in the development of special steel for shells and cannon, in the production of deadly gases, and other means of accomplishing utter and complete destruction, it has been equally active in discovering agencies for combating the effects of these terrible substances and alleviating the suffering which they cause, in finding substitutes for needed commodities, and in developing new industries to supply articles, formerly imported.

The public is also coming to appreciate as never before the need of a wider dissemination and utilization of chemical knowledge if economic independence is to be ours in the keen competition which will follow the advent of peace. High-school chemistry teachers have a very real opportunity in the present situation to emphasize the need of more efficient use of our natural resources and of the production, adequate for all our needs, of dyes, potash, drugs, nitrates, and other chemicals of fundamental importance.

The increased application of chemistry to industry is likely to result in an increased interest in chemistry as a part of a complete education. High-school chemistry instruction, therefore, should not aim to develop trained chemists but to give to all students an intelligent understanding of the significance and importance of chemistry to our modern life which will serve as a basis of appreciation and future encouragement of chemical industry. This is the primary aim of the course in chemistry as taught in this school.

Chemistry teachers have been slow to adopt the project method of teaching, and only an extreme radical would affirm that this method is applicable without considerable modification of the course in chemistry. The objections which are commonly raised to teaching chemistry by projects or problems are as follows:

(a) Many problems and questions raised by pupils involve complex phases of chemistry, or ideas too advanced for their understanding. For example, the difficulty in getting proper dyes makes this a topic of considerable interest, but in the elementary chemistry course

it can be given only a very superficial treatment, and that well towards the end of the year. The manufacture of high explosives is another similar topic which involves technical matters of too great difficulty for the beginner.

(b) Many of the great principles of chemistry, because of the impossibility of direct or experimental proof, cannot be arrived at easily by the immature mind. They are philosophic concepts, which have to be accepted on the ground of their service to science and the useful conclusions which are based upon them; for example, the assumptions of the atomic hypothesis, or the rule of Avagadro.

(c) The array of principles and facts is so great that the student is almost helpless before them, and unless the basis for establishing relationships and controlling facts is first developed, there can be no appreciation of the scientific method and no proper organization of the information supplied by discussion, investigation, and experiment.

These reasons are not easily disregarded, yet some motive, some compelling inner desire is just as essential to educative effort in chemistry as in elementary science. How, then, can these opposing arguments be reconciled and a tentative basis for teaching chemistry be established? Does not the answer lie in the changing character of the pupil's interests and in the enlarged scope which his problems and projects may take on as a result of his growing abilities and his increased power to direct and focus them?

The test of a problem, its significance to the pupil, lies not in its concreteness or the useful application which it involves, nor the familiar associations which relate it to other problems, but in the degree to which the pupil makes it his own and identifies himself with it, because of his belief of its worth-whileness. Under skilful teaching, may not that question, which a year or even a few months earlier would have seemed abstruse and uninteresting, become a real, live, practical problem? In other words, does not the desire come to some pupils, and should it not come much more generally, to know what the constitution of things really is, what the atoms are, and what properties they possess; why the volumes of reacting gases have such simple relations to one another; or why the weights of equal volumes of gases show such striking regularities? The adolescent is easily aroused. He is not yet encased in a shell of limited and selfish interests. Ultimate causes and reactions appeal to him as perhaps at no other time of his life. If the chemistry teacher can kindle this inner spark of natural interest into the flame of real desire, then those matters which before

seemed dry as dust may take on a new and vital aspect and become as truly problems as any which have yet been found in the introductory science courses.

The laboratory work especially ought to deal with problems and questions which grow out of class and home study, problems having to do with the home, the farm, local industries, personal and civic welfare. Towards this end the titles of experiments can often be improved and made more suggestive by stating them in problem or question form. For example, instead of the title *Mordant Dyeing*, a better one is *Why are Mordants Used in Dyeing?* or, in place of *Equivalent Weight of Magnesium*, *How Much Magnesium is Needed to Produce a Gram of Hydrogen?* for *Analysis of Ammonia*, *What is the Most Economical Brand of Household Ammonia to Purchase?* The main idea of each experiment should be given definite statement at the outset. This may be stated as a purpose: *To Show the Method by Which the NaOH of Commerce is Prepared*, or as a question: *Does the Vinegar of Your Grocer Come up to the Legal Standard?* The mere statement *NaOH* or *Vinegar* at the top of the direction sheet is not suggestive and should be discouraged. There should be a logical sequence of experiments. That is, each experiment should not be all-sufficient to itself, but should grow out of the preceding work and at the same time have regard for the coming work.

The course in this school is given in the senior year with a time allotment of six periods per week, two of which are consecutive for laboratory work. Laboratory sections are limited to twelve each on account of the size of the laboratory. The same division into sections is maintained for one of the four remaining periods, so that it may be used for either laboratory or recitation purposes as required. It is based upon the following outline which shows the organization only upon broad lines and is followed by a number of type topics in order to illustrate to better advantage the method of teaching.

I. INTRODUCTORY STUDIES

(a) **CHEMICAL CHANGE.** Many illustrations and demonstration experiments to arouse initial interest; its chief characteristics as effecting matter and energy; its significance in a living and complex world.

(b) **OXIDATION.** A type of chemical change; its varied and more common applications; laboratory study of oxygen.

(c) **REDUCTION.** Relation to oxidation and its importance in the industrial world.

(d) **WATER.** Its importance in the economy of nature, physical and

chemical properties. Methods of decomposition, volumetric and gravimetric analysis and synthesis. Water as a solvent; effects of temperature change on solution. Methods of purification. Protecting Chicago's water supply. Excursion to local pumping-station. Laboratory testing of spring and mineral waters. Softening hard water. Industrial significance of this problem.

II. CHEMICAL LAWS AND HYPOTHESIS

(a) LAWS OF CONSERVATION OF MATTER, DEFINITE AND MULTIPLE PROPORTIONS. Equivalent or reacting weights.

(b) ATOMIC HYPOTHESIS. The fundamental assumptions justified as a basis for explaining a large variety of phenomena and observations, and as the keystone of chemistry.

(c) THE GAS LAWS. Taught for the purpose of measuring gases in the laboratory, as required for experimental purposes.

(d) THE LAW OF GAY-LUSSAC. Many illustrations from laboratory and demonstration experiments.

(e) THE RULE OF AVAGADRO. Derived from the previous study of gases. Determination of number of atoms in common gaseous molecules.

III. CHEMICAL ARITHMETIC

(a) SIGNIFICANCE OF THE FORMULA AND THE CALCULATIONS BASED UPON IT.

(b) CALCULATION OF MOLECULAR WEIGHTS OF GASES BASED ON EXPERIMENTAL DATA.

(c) EQUATIONS AND CALCULATIONS BASED UPON THEM. Great variety of problems, with emphasis on those of practical significance.

IV. ACIDS, BASES, AND SALTS

(a) LABORATORY STUDIES OF SODIUM AND POTASSIUM AS BASIC ELEMENTS FORMING HYDROXIDES.

(b) LABORATORY STUDY OF CHLORINE AS AN ACID ELEMENT FORMING HYDROCHLORIC ACID. Chlorine as a bleaching-agent. Chloride of lime; its use as a bleaching-agent and in the laundry.

(c) NEUTRALIZATION AND SALT FORMATION. Titration experiments of a practical sort, such as determining the acidity of vinegar.

V. CHEMICAL THEORIES

(a) SOLUTION AND ELECTROLYTIC DISSOCIATION.

(b) MASS ACTION AND CHEMICAL EQUILIBRIUM.

(c) PERIODIC LAW.

(d) ELECTROMOTIVE SERIES OF ELEMENTS.

VI. STUDY OF THE MORE COMMON ELEMENTS AND THEIR COMPOUNDS

(a) SULPHUR. Sulphur dioxide, sulphurous and sulphuric acids, hydrogen sulphide.

(b) NITROGEN. The atmosphere and its composition. The air in relation to health. The fixation of nitrogen. Ammonia and nitric acid. Explosives and war.

(c) HALOGEN ELEMENTS. Family relationships and distinctions emphasized.

(d) CARBON. Coal, water, and producer gas; excursion to gas plant. Graphite and carborundum. Petroleum and its products. Coke and by-products. Coal-tar and its derivatives. Conservation of these as a necessity to economic independence.

(e) THE COMMON METALS. Iron and steel; copper; aluminum; zinc; tin; and lead; many comparisons and contrasts in metallurgy, in physical and chemical properties; excursions to available plants.

VII. CHEMICAL INDUSTRIES

(a) LIME AND PLASTER. PLASTER OF PARIS.

(b) GLASS AND PORCELAIN.

(c) CEMENT AND CERAMICS. Excursion to Cement-Mill.

(d) PAINT AND PIGMENTS.

(e) PHOTOGRAPHY.

(f) BREWING AND ALCOHOL PRODUCTIONS.

(g) ELECTRO-CHEMICAL INDUSTRIES.

VIII. CHEMISTRY IN THE HOME

(a) CLEANING-AGENTS. Soap and soap-powders; polishing compounds; ammonia and analysis of household ammonia water.

(b) SPOT AND STAIN REMOVAL.

(c) DIRECT AND MORDANT DYEING.

(d) LEAVENING AGENTS. Soda and baking-powder; laboratory testing of commercial brands. Yeast and vinegar. Excursion to yeast-plant and vinegar-works.

IX. RADIO ACTIVITY

(a) THE RADIOACTIVE ELEMENTS AND THEIR PECULIAR PROPERTIES.

(b) THE NATURE OF MATTER (as indicated by the discoveries in this field).

TYPE TOPICS MORE FULLY OUTLINED

OXIDATION

After the laboratory preparation and testing of oxygen, to determine its physical and chemical properties, the topics and questions for assignment and discussion include the following:

How was oxygen discovered? How abundant is it?

How is rusting and decay different from burning?

What is spontaneous combustion, and how may it be averted?

Why is perfect combustion necessary in furnaces and steam-power plants?

Why is imperfect combustion dangerous in stoves and grates?

Why is coal dust explosive?

Questions of this sort are usually found at the end of chapters in the ordinary textbooks, and serve chiefly for review or for making application of the ideas brought out in the chapter. By reversing the order, and suggesting them to the pupil before he begins his reading, his home-study may be rendered much more purposeful and effective.

The class discussion answers the above questions and serves to bring out many others of a similar character.

TESTING AND PURIFICATION OF WATER

The initial laboratory experiment answers the questions:

What are the common impurities in water?

How may they be identified and removed?

This work involves sedimentation; filtration; tests for sulphates, chlorides, calcium compounds and other dissolved minerals; distillation, including fractional distillation; and boiling to destroy bacteria.

In a class discussion following the experiment, the importance of an adequate supply of pure water to every city, town, and community is brought out, and the question raised as to which of the methods studied in the laboratory can be carried out on a commercial basis. The need of more efficient methods is apparent, and the assignment to the reference books is based upon the following questions:

Why does a laundry need soft water?

What is boiler scale?

How may roily river water be made clear and safe for drinking?

How is our own water-supply protected and purified?

At the next recitation these questions are answered, and many others which are raised by members of the class. Demonstration experiments of the coagulation method of water purification, and of the softening power of commercial preparations, such as Permutit, are included. Specimens of boiler scale, a section of an old boiler-tube, and an old teakettle, are shown to the class. Excursions to pumping-station and municipal water-laboratory follow.

Another worth-while laboratory experiment is to have the class test the hardness of many varieties of natural spring and mineral waters, supplying their own samples from springs, wells, artesian water, or commercial bottled varieties. The work takes the plan of a rough analysis, and includes a determination of the percent of total dissolved solids; the identification of the mineral salts present as far as possible; the determination of the degree of hardness, using a

standard solution of liquid soap; and a spectroscopic examination of the residue from evaporation of a sample.

TESTING FOOD PRODUCTS

This topic is introduced by asking the class how much of the food they eat is preserved? Copies of a few menus from the school lunch-room are shown, which make it clear to all that food preserved in some manner constitutes a large percent of that normally consumed. This suggests the following questions:

Are foods preserved in certain ways injurious?

How is the public protected from the improper use of preservatives, adulteration, and misbranding?

What are the preservatives likely to be found in various products?

How may they be identified?

The assignment covers these questions and copies of the *National Pure Food and Drug Acts* are placed on the reference shelf. The class discussion has as its outcome a conception of the complex machinery of national and state supervision of food products, and of the kind of problems with which a food chemist must deal.

Pupils are asked to provide themselves with samples of all sorts of food for the laboratory testing, which immediately follows this discussion. In order to secure a choice of samples worth testing, the laboratory direction sheet is given out in advance. It supplies directions for testing food-products for:

Sulphur dioxide or sulphites in dried and preserved fruits and meats.

Coal-tar dyes in candy, preserves and ices.

Flour or starch in candy and jellies.

Alum, copper, and tumeric in pickles.

Boric acid or borax in crackers or ice-cream cones.

Reference books for other tests are at hand to meet any particular problems that seem worth while in individual cases.

Following this laboratory work, the next recitation calls for a general summing up of results, so that the scope of the testing is apparent to all.

FIXATION OF NITROGEN

This topic is one of particular interest and affords exceptional opportunity to bring home to the pupil the wonderful achievements of chemistry in this field.

After the composition of the air has been studied and determined in the laboratory, these questions naturally arise:

Does the nitrogen of the air serve any useful purpose?

Can this vast quantity of nitrogen be turned into useful products?

What compounds of nitrogen are needed, and for what purposes?

With these questions as a basis, the class is given an assignment to the textbooks and reference material bringing out the importance of nitrogen compounds; of nitric acid for explosives, celluloid, and gun-cotton; of ammonia for munitions and refrigeration; of nitrates for soil fertility. The class discussion serves to emphasize the vital need of all these products and their manufacture in large quantities. In this discussion are included the following topics:

The nitrogen cycle, which is fully worked out and discussed.

The Birkland-Eynde and Haber processes for making nitric acid.

The Oswald process for making cyanamide and ammonia.

Coal as a source of ammonia. The wastefulness of the beehive oven is compared with the efficient utilization of the full value of coal in by-product ovens. The necessity for conserving the nitrogen compounds coming from coal is emphasized.

The final question under this topic is: What is being done in our own country to supply our needs for nitrogen compounds?

Newspaper clippings, magazine articles, etc., are of use in bringing this question right up to the minute and driving home its significance.

SOAP AND CONSERVATION OF FATS

The demand of the government for conservation of fats as a war measure makes an especial appeal to this topic at the present time.

Why are fats important in time of war? This question involves the recovery of glycerine as a by-product in soap-making and its conversion into nitro-glycerine and dynamite. Members of the chemistry class have a real opportunity to aid in this conservation movement, and to see to it that no fat is wasted in their homes, and that all not used for cooking is converted into soap. The production of a good soap, from any accumulation of waste fat, no matter how rancid, is a laboratory experiment of special merit. It brings home the practical usefulness of the chemical knowledge acquired not only to the pupil but to parents and friends as well.

This experiment can be done at home as well as or better than in the laboratory. In this way it tends to correct the rather prevalent notion that chemistry experiments are limited to the school laboratory.

It will usually be found profitable to have pupils obtain recipes for making soap from home and other sources, and work out the final laboratory direction sheet as the result of testing. Pupils can be of real service to the cause of conservation by spreading the propaganda of home-made soap as the best way to utilize waste fat.

The following recipe, as a laboratory direction sheet, has been tested by a number of pupils and found to give good results.

MAKING SOAP FROM WASTE FAT

Materials: 6 lb. fat (accumulated drippings of any kind); $\frac{1}{2}$ lb. borax; 1 can Babbitt's lye (crude NaOH).

Dissolve the lye and the borax in 3 quarts of hot water, in an iron or enameled dish, and allow to cool. Melt the fat and strain through two layers of cheese-cloth, and allow to cool until pasty but not hard. Add the lye solution slowly to the fat, a little at a time, and with thorough stirring. After all is in, stir slowly for ten or fifteen minutes, until the soap thickens. If the soap does not thicken after fifteen minutes of stirring, give it an occasional stir until it does become pasty. Pour out into a pan lined with waxed or oil paper. When hard, cut into bars.

If a perfumed soap is desired, from 1 to 2 oz. of oil of lavender may be stirred in before pouring out. Coloring material may also be added at the same time. Instead of pouring into a pan, small pasteboard boxes, such as match-boxes, may be used as molds with good results.

